



**Approaches to the evaluation and selection of New Technologies in the  
Animal Health sector: Review of articles – Existing methodologies for  
Technology Evaluation and Selection**

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## **1. Introduction**

The objective of this review is to scan worldwide for existing methodologies in order to adopt an optimum approach to the elaboration of a method to identify new technologies for the Animal Health sector in the DISCONTTOOLS project framework.

It was emphasised in the Action plan of the European Technology Platform for Global Animal Health (ETPGAH) that a fundamental problem for Europe was the inability to identify potentially successful innovations and to develop these into products. The main hurdles are finance, understanding of the process by the research scientists and a system that identifies innovation and is able to develop the idea to a stage where it can be manufactured and authorised.

The objective is to develop and deliver a comprehensive, harmonised and validated methodology for the identification and selection of new technologies to help prevent and control animal diseases. This can only be done with a full cooperation between research, industry and users. This review aims at scanning the available information on Technology Evaluation and Selection, thus helping identifying an optimal methodology applicable to the animal health sector. The final goal of this exercise will be to give more focus and clear priorities in research funding to bring products to the market and shorten the development time frame.

There are two ways of looking at innovation and new technologies: one can start with a problem to solve and find technology solution to address this problem, one can look around in other sector in literature and conferences to detect new technologies that could be applied in a different area. This paper will try to gather both approaches and highlight the various methods applied in those two cases.

Approaches to the Identification and Evaluation of New Technologies have already been developed by various organisations and Universities with different models and goals. In this review, 8 articles and 2 programmes from very different sectors (such as farming, aeronautics, mobile phones, public transportation...etc) are examined.

## **2. Information gathering**

Necessary information to conduct this review was gathered from different techniques and sources. Initial scanning involved performing internet web searches on items such as ‘Technology evaluation’ ([www.google.be](http://www.google.be)), and visiting the websites of related organisations.

Searches on peer reviewed literature were conducted using the PubMed database and Elsevier website. DISCONTTOOLS Work Package 4 members on “Technology Evaluation” were also asked to give some input on existing methodologies for priority setting.

### **3. Priority setting in selected articles**

#### **3.1 Scanning methodologies**

##### **3.1.1 FutureWatch programme – New Zealand Ministry of Research, Science and Technology**

###### **3.1.1.1 Objective**

This programme is a giant scanning exercise started in 2006 in New Zealand. It aims to build government's alertness to innovation and technologies and the possibilities of implications, in terms of opportunities and risks that they present to the country. It is indeed a kind of 'radar', a way of systematically scanning the external environment.

The scanning network is intended to provide good intelligence to the Ministry Science & Technology policy development, while representing an information service to other agencies. A key objective is to find ideas and technologies that are new or unusual and that may represent signs to important changes in the near future. Another aspect in this Futurewatch programme is thinking about the impacts of new science and technology worldwide.

###### **3.1.1.2 Methodology**

Objectives are tackled by stimulating discussion and producing material that supports various Ministry departments to factor emerging science and technology into their policy work. The work also includes providing alerts to important research questions, new opportunities for research or considerations of the role of new knowledge, innovation and the RS&T sector in issues of strategic importance to New Zealand.

This programme initially started out with a detailed piece of work looking at likely developments and applications in the area of biotechnologies only. This preliminary work has illustrated the need to undertake a less intensive but ongoing scanning capability to continue monitor trends and developments. Initially, this has been handled by contracting out the scanning. The contractors recruited a range of people from the science sector and non-governmental organisations to provide short observations on some developments. Then, they attempted to make sense of this information through workshops with government agencies. The main purpose at this early stage was to make government agencies aware of emerging technologies and help them consider the implications for the agencies' areas of interest.

During this first scanning exercise good observations were picked up, but the Ministry realised that scanners were not all experienced in the concerned domains and many of them dropped out during the first two years because they found it took up too much of their time and/or they were not finding it very rewarding.

In a second step the Ministry took over direct management of the scanning network. They focussed on more clearly identifying what topics and types of information the government agencies are interested in, and letting the scanners know this so they are better able to meet the needs of their audience. The main agencies involved in this Futurewatch programme are the Ministry of Agriculture & Forestry, Ministry of Health, Ministry for the Environment, NZ Food Safety Authority and the Environmental Risk Management Authority.

Training is provided to scanners to help them become better in their work and understand better what is asked from us. Scanning observations are transmitted to the Ministry and feedback is provided to scanners on whether scanning information was useful or not, suggesting sometimes where additional information would be useful, and/or reframing the information in a way that will be more likely to hold the attention of other policy analysts.

Scanning observations are disseminated on the programme's website in a "Shared Workspace" which corresponds to a member's area. Some results are also available publically. Scanning reports are only 1 or 2 pages long specifying potential implications and applications of new technologies. A poster entitled 'Panoptic' has been designed, summarising the trends and scanning observations gathered in 2008 and 2009. This document is intended to stimulate thinking about future implications for New Zealand of scientific trends and developments. Workshops are also organised to stimulate discussions about the implications for some of the trends and developments. They are using a facilitator who is experienced in Futures work to run these. A focus of the workshop is to also demonstrate how to use Futures work in everyday situations to demonstrate that it has practical value now. Publications and presentations in relation to Futurewatch are also available on the website.

### **3.1.1.3 Conclusion**

This programme illustrates what can be done in terms of forecasting at government level in a country. The process here is looking at what exist outside a sector or country to think about future applications in science. In this case this is not a problem that needs a solution but solutions that need applications.

One of the challenges faced in this programme is that there is a diverse range of interests to try and cater to, so not everything the scanners provide is relevant to many of the audience. Another challenge is finding the right people to be scanners. It is important to try and get them to provide insights into their areas of expertise.

Connection with other Futures projects exists and is particularly useful for areas not covered by the scanners expertise (currently 8 active scanners not covering all the scientific areas). For areas of expertise the challenge is to provide information in a way that is useful to other agencies: through the website, short scanning reports, workshops, the shared workspace.

Finally, it seems clear that the core of this Futurewatch programme is the Scanning Network. It is a very interesting programme to learn from with a rather simple functioning. The main difficulties are to select optimum scanners, keep them interested and gather a huge amount of information to analyse. Futurewatch seems to deliver most of the objectives of DISCONTTOOLS WP4 with an innovative and original methodology for technology selection.

## **3.1.2 United-Kingdom Foresight Programme**

### **3.1.2.1 Objective**

Foresight is a UK programme from the government. It was launched in 1994 and brings together experts from industry, government and academia into sector-facing Panels to explore opportunities in different sectors of the economy. Foresight, together with the Horizon Scanning Centre, aim at producing visions of the future to ensure effective strategies are designed now, by providing a core of excellence in science based futures expertise and access to leaders in government, science and business.

The key objective is to improve the relative performance of UK science and engineering and its use by government and society. To achieve this, the Foresight programme tries to identify potential opportunities for the economy or society from new science and technologies, or considers how future science and technologies could address key future challenges for society.

This work is supported by the Horizon Scanning Centre, whose aims are to inform decision-making both within government departments and across departments; to support horizon

scanning being carried out by others inside and outside government; and, spot the implications of emerging science and technology and enable others to act on them.

It is essential to bring together key people, knowledge and ideas to look beyond normal planning horizons to identify potential trends and applications from new science and technologies, while developing actions to effectively encourage application when opportunities exist.

### 3.1.2.2 Methodology

To achieve such ambitious objectives they have developed a rolling programme of between three and four projects. A project can be a key issue where science can offer possible solutions or an area of cutting edge science where the potential applications and technologies have yet to be considered or articulated more broadly.

Topics for future Foresight projects are identified through a range of consultative processes. The Horizon Scanning Centre ran strategic scans, the results of which feed directly into project selection process. Brainstorming meeting of senior academics are organised to identify possible topics; the first brainstorming produced a list of topics, a number of which formed the basis of most of the projects that Foresight has run since 2002. The suggested list of topics is then posted on the Foresight website for comments, and in parallel the Foresight team will be consulting industry, academia, government departments, and devolved administrations to seek their views.

For a topic to be shortlisted as a possible project it has to satisfy the following criteria:

- Be future-oriented, and based upon science and technology
- Not duplicate work taking place elsewhere
- Have action-oriented outcomes that can be influenced by the work of the project
- Have buy-in and commitment from all key stakeholders; and
- Involve cross-disciplinary science and technology, and cross-Departmental policy issues.

If a topic fulfils these criteria it can be included on the short list for future projects. However, the constraint of Foresight is to be only able to run four projects at the same time.

A high-level stakeholder group with senior decision-makers and budget-holders from relevant Departments, Research Councils and other organisations, oversees all projects. The group is chaired by the Minister from the lead Department, and is responsible for agreeing an action plan, which is usually published alongside the findings and reports of the project. Each project is led at a senior level by the Chief Scientific Adviser. Projects usually last between 12 and 18 months.

Reviews research literature and horizon scanning represent the main activities in each project, taking into account relevant social and economic trends. Participants are supported by in-house teams, helping pull together information and make the right cross-connections. A network of experts and stakeholders also work closely with the Foresight project teams.

Futures techniques are also used to ensure current trends and current technologies are not simply projected in the future. This can be done by using tools such as scenario planning, but the methods varies depending on what the project is covering. A Foresight project does not predict the future, but it tries to identify a range of possible outcomes by analysing the trends and the environment.

Output from the programme will be to inform and influence policy and the decisions of research funders, including business, Government departments, and charities, as well as the directed programmes of the Research Councils and the overall strategy of the Director General of the Research Councils. However, UK Foresight does not produce a national research strategy, or direct the priorities of Research Councils or the Government Office for Science.

### **3.1.2.3 Conclusion**

This programme is quite similar to the NZ Futurewatch Programme although it has developed a different methodology to achieve the same objectives. Again panel of experts from various background and expertises are used to scan for what exists, but through projects that have to be accepted.

In 2006 a project on infectious diseases was launched. This project took a holistic perspective and considered how to manage the future threats of infectious diseases in plants, animals and humans. This project will be of great help to DISCONTTOOLS as it is already well advanced and has published a one-year review document.

This approach seems relevant and could be used as a model for the work of WP4. However it is a big-scale programme, in application for an entire country, involving a lot of people and resources.

### **3.2 Methodologies aiming at identifying a problem and evaluating alternatives**

#### **3.2.1 “Development of New Methods of Technology Selection in Integrated Research Project”**

##### **3.2.1.1 Objectives**

This research was conducted by the Japan International Research Center for Agricultural Sciences (Japan), the Mekong Delta Farming Research and Development Institute (Vietnam) and Tokyo University of Agriculture (Japan).

The aim of this paper is to help developing technology in integrated research projects based on the needs of farmers. Many technology development projects in the field of agriculture do not pay attention to the stakeholders needs and have sometimes to change the direction on the way of a technology selection project to re-adapt it to ‘real’ needs. The article proposes a new method of technology selection with an active participation of farmers to better understand their needs and constraints.

##### **3.2.1.2 Methodology**

Three different methods are described: TH-Methods, KJ-Methods and AHP-Methods. TH-Methods are decision support systems of inhabitants for finding, evaluation and selection of rural revitalisation means under the limitation of time and budget (Monma 1996). It helps to list problems and requires farmers to score each problem according to seriousness. KJ-Methods help solving problems by connecting cards containing data (Kawakita 1986). Finally, AHP-Methods (which stands for Analytic Hierarchy Process) aim at supporting the decision-making when some options with conflicting appraisal standards exist (Tone 1986).

The study was conducted in Tan Phu Thanh village by asking farmers to communicate on problems in terms of technology and management. 50 farmers were asked to score the various problems to make priority of each problem clearer. After selecting problems with relatively higher priority they conducted the KJ-Methods to summarise problems.

Next step was the creation of a list of possible solutions to the identified problems. These solutions were then translated into research topics by an interdisciplinary team . AHP-Method was conducted by listing several technologies as options, their comparison one by one with the appraisal standards (such as effects, technology level, ease for farmers and research costs). For each standard a score was attributed and the total score for one technology was calculated by adding all scores gathered.

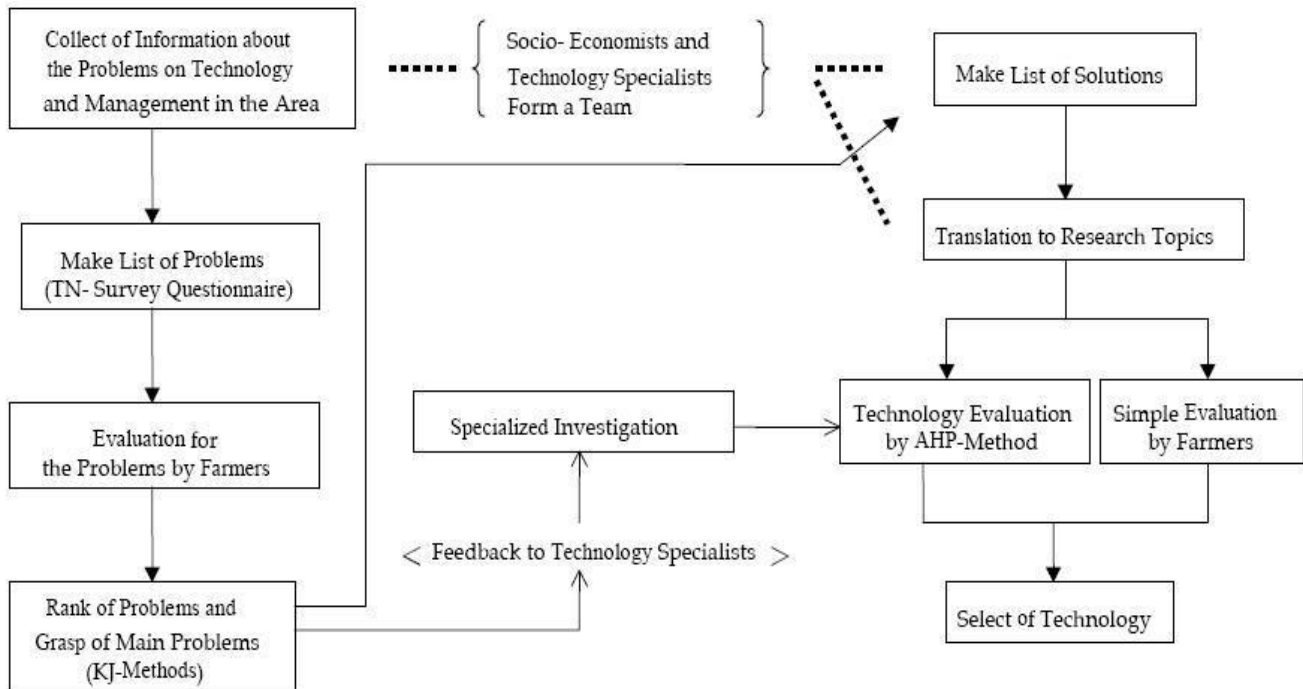
Results showed that research topic entitled “Development measure to keep or improve soil fertility” had the higher score following the three methods. In parallel as these methods were too difficult for farmers to follow, farmers were asked to score each research topic according to their importance from a farmer point of view. “Development measure to keep or improve soil fertility” was also scored the highest with this approach. The author selected this technology to be developed, but also technologies in other research fields that were scored high.

##### **3.2.1.3 Conclusion**

This methodology is a good illustration of what is done to ensure new technologies are identified and selected quickly in the agricultural sector. The focus is mainly on identifying problems facing the farmers, developing research to find potential alternative solutions and evaluating and comparing the alternatives proposed to select the most appropriate technology for use. This method finds application when starting with a problem to solve or a gap to fill; it

is not intended to scan widely the existing and developing technologies. However, the process is interesting with the involvement of the farmers and a team of socio-economists and technology specialists: it clearly highlights the need for a holistic approach when looking at innovation. The overall process is illustrated below:

**Figure 1: Procedure of the Methods of Technology**



Source: “Development of New Methods of Technology Selection in Integrated Research Project” – Ryuichi Yamada, Nguyen Quang Tuyen, Le Canh Dung, Toshiyuki Monma, and Vo Van Tuan – 2000

### 3.2.2 “A methodology for the selection of new technologies in the aviation industry”

#### 3.2.2.1 Objective

This paper has been written by researchers from Cranfield University to present a technology selection methodology to quantify both tangible and intangible benefits of certain technology alternatives within a fuzzy environment. In the aviation sector it is highly difficult to clarify the right technology alternative or choice because the number of available technologies is rising and also because these new technologies contain increasing amount of complexity. The sector is facing a lack of defined methodology to select new technologies and processes, although a correct selection could create a significant competitive advantage.

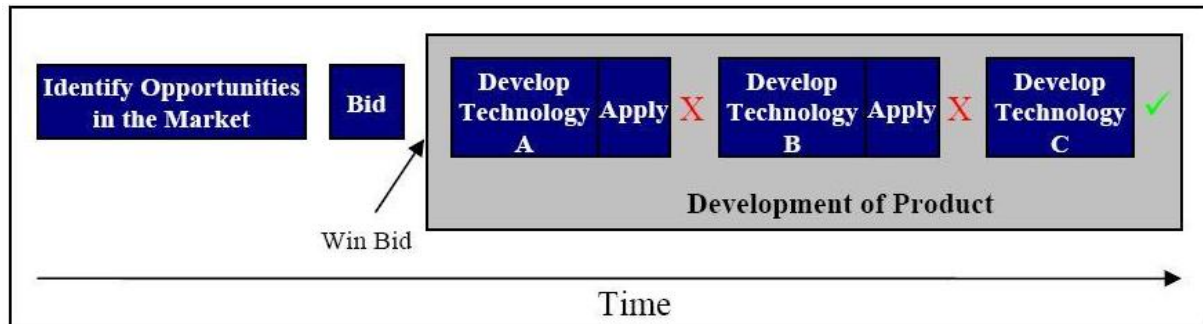
This article proposes interesting ideas about the definition of new technologies, the challenges in new technology selection and related research. They propose two parts in the definition of “New Technology” which are defining what is ‘new’ and what is the ‘technology’ that is new. Three classification levels exist for the term ‘new’: new to mankind, new to the industry and new to a company. Regarding the definition of new ‘technology’ it can be a design concept that is developed to become a product or a new manufacturing process. The main challenges encountered are: the lack of experience on something that is ‘new’ regarding life cycles, resources or application techniques; and the limited understanding of processes for the selection of any new technology. Existing research in the area are extensively presented with various economic, strategic and analytic techniques; their advantages and weaknesses.

### 3.2.2.2 Methodology

The main problem at the aviation subsidiary company is the fact that they develop new technologies only after the bid has been won. In other words technology development is conducted within the individual projects' timescale and budget and if the technology newly developed doesn't meet all requirements, extra costs and time delay occur.

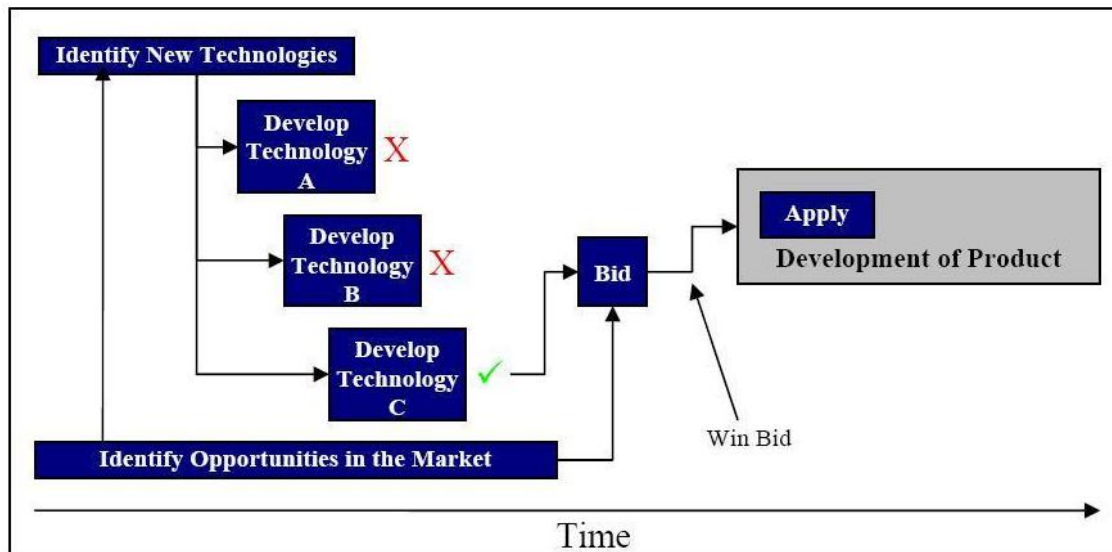
Two figures illustrate current and ideal methods:

**Figure 2: Current method of new technology development**



Source: "A methodology for the selection of new technologies in the aviation industry" – Oliver Houseman, Ashutosh Tiwari and Rajkumar Roy – November 2004

**Figure 3: Ideal method of developing new technology**



Source: "A methodology for the selection of new technologies in the aviation industry" – Oliver Houseman, Ashutosh Tiwari and Rajkumar Roy – November 2004

These figures show that if some of the technology was developed or acquired by the aviation subsidiary company before the bid procedure it would enable bids to be submitted that were more accurate and less risky.

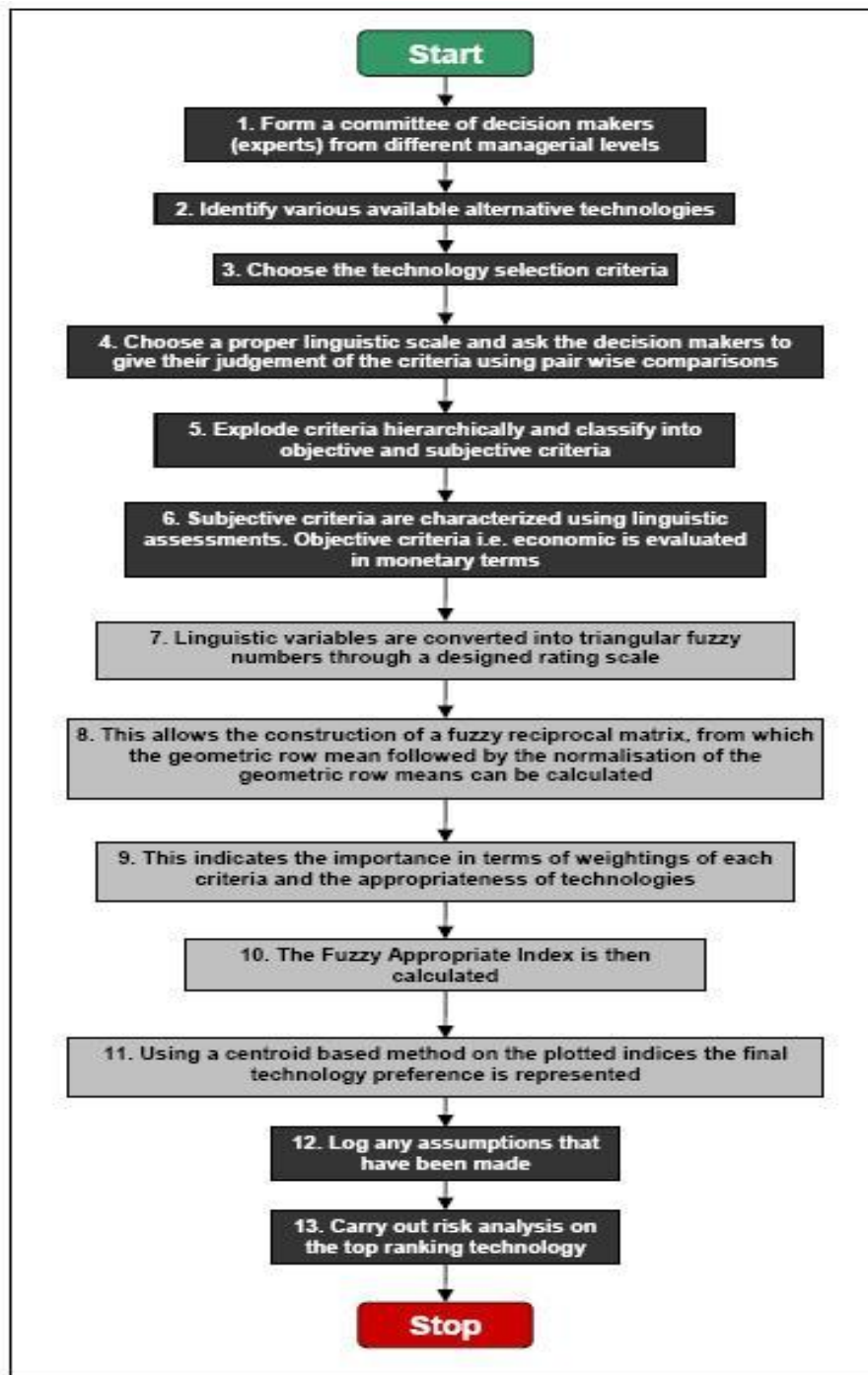
First step of the methodology explored is the Identification of New Technology that meets the company requirements through in-depth literature reviews by a research officer. Another important point in identifying new technology is the customer knowledge.

The method follows 13 steps of which steps 7 to 11 involve the use of computer model. This latter is based upon the methodology presented by Chan et al. (2000) and is used to capture

the linguistic descriptions of the relative importance of the subjective criteria and a range of possible values for the objective criteria. The result of this model is a ranking for each of the technology alternatives in order of suitability, after comparison against all the criteria. The model aims also at providing a tool to record all decisions made and keep a track of them.

This allows review in the future. Finally, this methodology recommends carrying on a risk analysis on the top ranked technologies. The recommended methodology in its entirety is illustrated below:

**Figure 4: Proposed methodology**



Source: "A methodology for the selection of new technologies in the aviation industry" – Oliver Houseman, Ashutosh Tiwari and Rajkumar Roy – November 2004

The essential evaluation criteria identified from a results-orientated point of view are: cost, quality (fulfilment of functions, ease of diagnostics, robustness and image achieved) and flexibility. In the article they also mention other important criteria such as the degree of maturation of the technology as a measure for the development uncertainties or risks during the product development phase. The model prototype has been developed in Excel and the article presents a case study to better illustrate its functioning.

### 3.2.2.3 Conclusion

On discussion they state that it is an easy-to-use tool to calculate all of the complex fuzzy set theory, addressing the requirements for explicitness, consistency, simplicity, flexibility, decision-maker participation, decision-process quality and decision quality. The fact that Excel was chosen allows users to graphically alter their judgements and see how it influences the weightings.

One limit would be the lack of a module conducting sensitivity analysis on the output to evaluate the minimum change required in the weight of a criterion to create rank reversal among alternatives. A constraint is that more than one technology has to be available for such methodology as well as sufficient expert opinions. The authors specify that it is not intended to replace human judgement in technology selection and that it is a tool to help decide on alternatives. The fuzzy logic was used in this article to deal with uncertainties and give decision-makers the flexibility of using rough estimates and linguistic terms to describe the criteria used.

This methodology does not start by identifying problems to solve but market opportunities linked to the development of new technologies. Again they insist that an expert committee is needed to seek advice on the various alternatives once potential new technologies have been selected. Balancing the risks and benefits is compulsory and it is well illustrated in this article in a sector such as the aviation where the aim is to ensure safe transportation.

This paper recommends conducting further research to benefit some areas such as sensitivity and risk analysis. This model is described as ideal for developing strategies for future products that are only at the concept stages of development.

## 3.2.3 “A Method for Technology Selection based on Benefit, Available Schedule and Budget Resources”

### 3.2.3.1 Objective

This study was conducted by the Engineering Society for Advancing Mobility Land Sea Air and Space International (SAE International) and the American Institute of Aeronautics and Astronautics (AIAA).

The first concept developed in this article is the identification of the paradigm (“...collection of beliefs, theories, standards, and methods shared by scientists that guide research efforts.”) in a particular sector: aerospace systems. Once a crisis occurs that may highlight the inadequacy of the current paradigm, only an intellectual revolution can help replace the old paradigm with a new one. This is called a “paradigm shift”. The Technology Identification, Evaluation and Selection methodology presented here, could propose a possible solution to this shift in paradigm.

The authors explain that this paradigm shift is based on multiple contributing factors that exist in a changing global environment. The current NASA administration has noticed the shift that recently occurred in aviation focus and has created the “Three Pillars for Success” program.

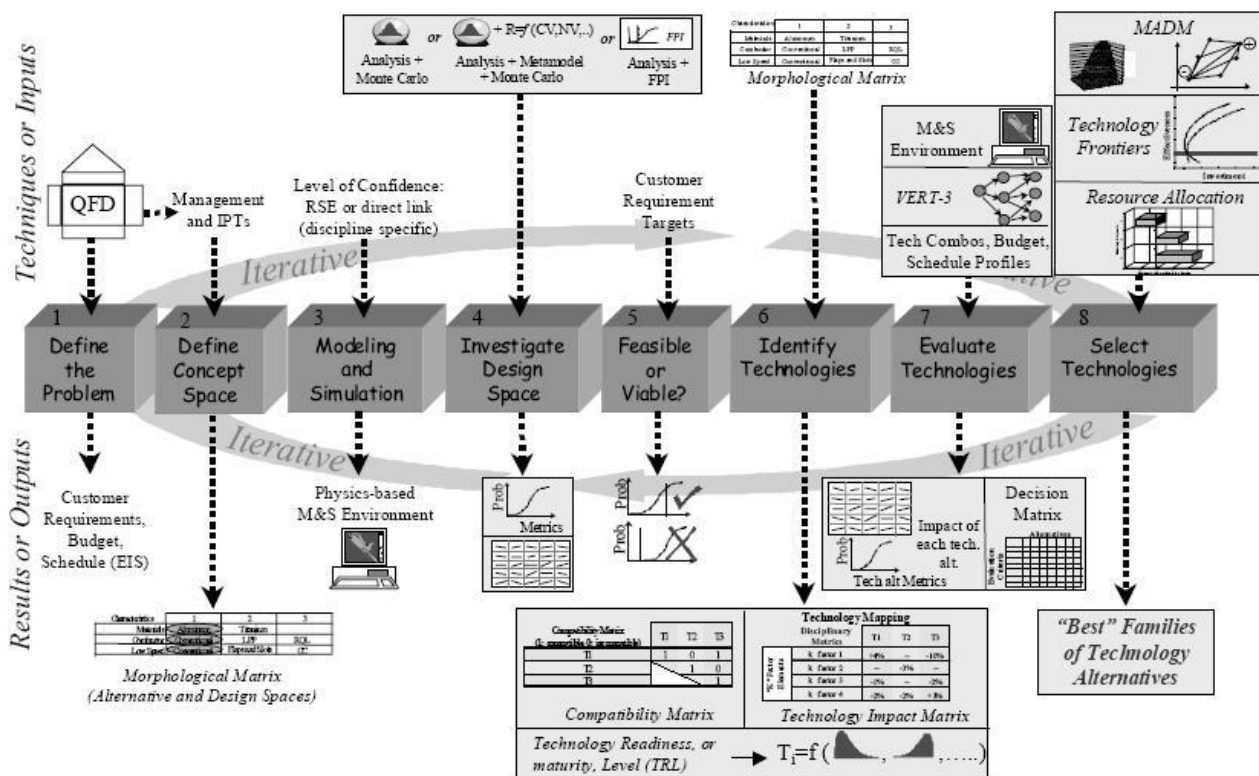
The first pillar is the life-cycle of a technology because the majority of the costs incurred are locked in early in the development process. The NASA explain that making educated decisions early on and maintaining a family of alternatives without locking in the costs is the key to success of the paradigm shift. The second pillar is dedicated to new methods needed for evaluating designs that can integrate the multiple, usually conflicting objectives (criteria) to identify design alternatives that may be the “best” solution to satisfy all criteria. The last pillar identified is the need for technological breakthrough in a changing environment driven by economic incentive and where conventional or existing technologies are usually preferred.

The time needed to launch a concept and sell it as product is usually important (8 to 15 years in aerospace) and a technology is often obsolete when finally used. The authors insist that technology forecast has to be made to help reducing the uncertainties that come from a new technology. They conclude that “a rapid, systematic and methodological forecasting method or environment is needed which can quantify next-generation concept performance, economic and risk aspects and compare these results to future goals. The method should be designed to account for multiple objectives and constraints under uncertainties and conflicting objectives while considering technological and economic risks.

### 3.2.3.2 Methodology

This paper presents the “Technology Identification, Evaluation, and Selection (TIES)” method, which can help respond to the paradigm shift in aerospace systems. It is an eight step process illustrated below:

**Figure 5: Technology Identification, Evaluation, and Selection Method**



Source: “A Method for Technology Selection based on Benefit, Available Schedule and Budget Resources” – Michelle R. Kirby and Dimitri N. Mavris – 2000

TIES method starts with the definition of the problem by mapping the customer requirements into quantitative data. Next, a potential class of concepts (e.g. criteria such as high capacity, long range, subsonic transport class) are identified that may fulfil the customer requirements. A functional decomposition of the class of vehicle is performed via a Morphological Matrix to identify concept alternatives.

From this matrix, they establish a baseline vehicle and a design space bounded by control variable such as wing aspect ratio, engine thrust etc. this space is investigated for system feasibility by complex modelling. The comparison of all possible alternatives is done via the Technology Impact Matrix (TIM), then the technologies are combined and evaluated at a theoretical limit and are subjected to technological uncertainties. Impacts of the different technology mixes are estimated and combined in a decision matrix.

The final step is the one developed in more details in this article: technology selection under uncertainty. Three approaches are proposed: scoring models, technology frontiers and resource allocation. The article develops these three methods in depth and gives a concrete case study which finally results with the selection of three significant technologies with identical results from the three methods proposed.

### **3.2.3.3 Conclusion**

They conclude that three approaches were needed to capture the technological uncertainty associated with immature technologies within the selection process and the multidimensionality of design requirements. TIES method seems rapid and efficient and may be easy to adapt for different program assumptions. It will help reduce time and cost needed to develop new technologies and provide quantitative justification for design decisions.

Again, this paper describes a methodology for use when starting from a problem to solve and looks at finding solutions through the use of new technologies. This is only a part of the identification and selection process as the institutes involved are not here interested at scanning widely (out of their own sector) what exists to find application to other technologies in their area.

### **3.2.4 “A multi-actor, multi-criteria approach for technology selection when designing mobile information systems”**

### **3.2.5 “A Multi-stakeholder Multi-criteria Assessment Framework of Mobile Payments: An Illustration with the Swiss Public Transportation Industry”**

Those two articles were written at the Universities of Lausanne and Hawaii and will be presented together as they are presenting the same methodology. The first one expresses general views and applications. The second one gives a concrete illustration of the method.

#### **3.2.5.1 Objective**

In our current societies the number of new technologies is constantly increasing although the design of new mobile application systems raises critical technical and business issues. This is mainly due to the existing uncertainties about the success or failure of a new technology. The appropriate selection of technologies is a key and choices have to be addressed during the design process.

The authors state that there is a need for a structured approach in mobile information systems and propose to develop a model using multi-criteria decision making (MCDM). This could help having a more transparent decision process while addressing complex problems with incomparable objectives, multiple stakeholders and conflicting interests. The aim of these two papers is to illustrate the feasibility of using MCDM methods to select enabling technologies in the design process of information mobile systems.

#### **3.2.5.2 Methodology**

MCDM procedures have proven useful in supporting decision making and some attempts were done to use MCDM to assess technologies. MCDM methods were recognised to be rigorous and transparent in foresight process. The authors define six steps to be followed during the selection procedure.

They are as follows:

- Definition of the problem and its alternative solutions
- Identification of the stakeholders
- Definition of selection criteria
- Selection of the technique of preferences aggregation
- Evaluation of solutions in respect to each selection criterion
- Search for consensual solution

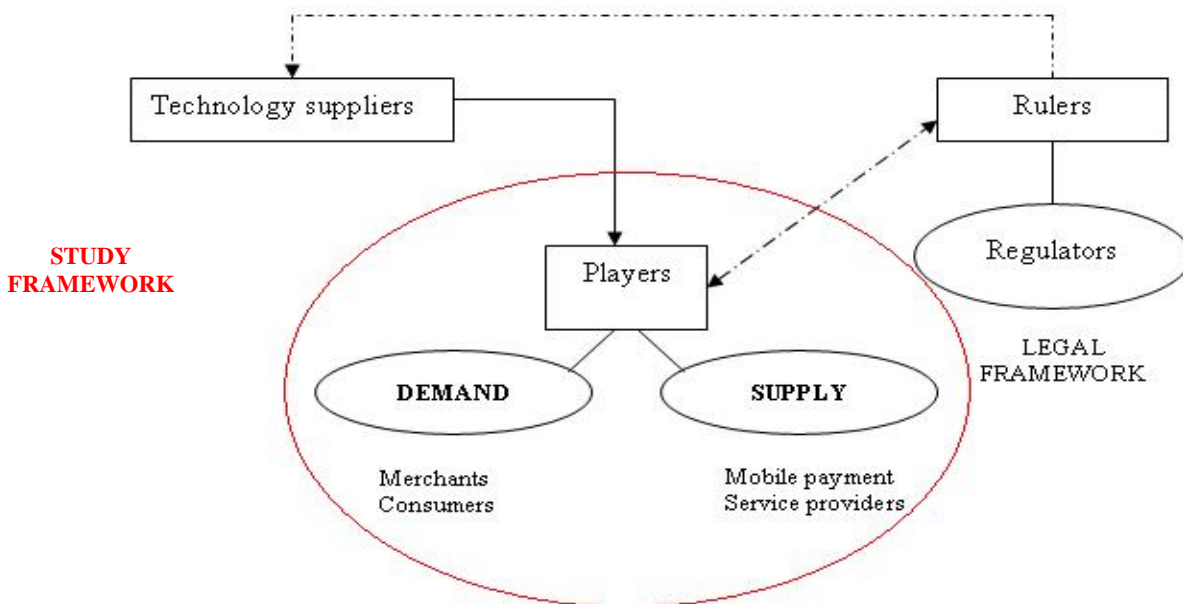
In both papers the mobile payment industry is used as an illustration of the methodology. Data used are derived from an extensive research in the literature, from opinion of few experts, and from interviews.

In the definition of the problem and its alternative solutions they use the case of mobile industry. A vast range of wireless technologies have recently emerged to produce new mobile products and services, and could be used for mobile payment services. These technologies differ in their capabilities but also in their impact on the different stakeholders. In this paper three technologies are selected: contactless card embedded with a RFID (Radio Frequency Identification) tag; mobile phone using proximity networks such as Bluetooth, RFID and Infrared; and mobile phone using remote networks (e.g. GSM, GPRS, UTMS, WLAN). They are all suitable for mobile payment but present different advantages and weaknesses. For benchmarking purposes, they introduced two very popular payment technologies such as

magnetic cards (e.g. VISA) and smartcards (e.g. Proton). This is to compare the new technologies with the existing ones, representing a reference point, and giving a good insight in the current market.

A classification of the different stakeholders is made with actors directly involved (players) or indirectly involved (rulers). The rulers are responsible for the legal framework (regulators) whereas diverse actors (technology suppliers) are in charge of providing the technology to the players. Those latest represent the demand (merchants and consumers) and the supply (mobile payment service providers). An illustration is presented below:

**Figure 6: Stakeholders Groups**



*Source: designed from the text in the article entitled "A MULTI-ACTOR, MULTI-CRITERIA APPROACH FOR TECHNOLOGY SELECTION WHEN DESIGNING MOBILE INFORMATION SYSTEMS", page 4 – Jan Ondrus, Tung Bui and Yves Pigneur - 2005*

For this research they only included the players as the success of a mobile payment scheme necessarily depends on their adoption. Three stakeholder groups were formed: provider, merchant, and consumer. A general consensus is assumed about the issues among a same group (one group = one voice).

Criteria are used to capture views that decision-makers use as a frame for reference in the selection process. They have to be comprehensive, and able to represent a rather complete perspective of the user with regard to the problem. Criteria adopted in this study are derived from the literature and represented as follows:

**Table 1: List of the stakeholders' criteria**

Provider	Merchant	Consumers
Cost	Cost	Cost
Organizational change	Customer base	Ease of use
Security	Ease of use	Expressiveness
Standard	Reliability	Trust
	Security	Universality
	Value proposition improvement	Usefulness

*Source: designed from the text in the article entitled "A MULTI-ACTOR, MULTI-CRITERIA APPROACH FOR TECHNOLOGY SELECTION WHEN DESIGNING MOBILE INFORMATION SYSTEMS", page 4 – Jan Ondrus, Tung Bui and Yves Pigneur - 2005*

MCDM allow analysis of criteria simultaneously or concurrently. The criteria can be quantifiable or non-quantifiable. Multiple objectives often work against each other so that the improvement or achievement of one criterion can be accomplished only at the expenses of other criteria. MCDM also allow decision-maker subjective evaluation to be considered by weighting the evaluation criteria, making pair wise judgements or by giving an ordinal ranking of a subset of alternatives.

They chose ELECTRE I (Benayoun et al., 1966) as a technique of preference aggregation for mobile payment services. ELECTRE I gives the possibility to model a decision making process using the concordance and discordance indexes and the outranking relations. The concordance index measures the degree of dominance of one action over another, based on relative weightings of the decision criteria. Conversely, the discordance index measures the degree to which an action is worse than another. Outranking relations are obtained with a combination of a high level of concordance and a low level of discordance.

ELECTRE I propose a subset of alternatives as opposed to a 'best solution'. To evaluate the solutions, stakeholders are requested to score the different alternatives against each selection criteria. The table below gives a concrete example for the provider group:

**Table 2: Evaluation by the provider group**

Criteria	Weight	Magnetic card	Smartcard	Contactless Card	Mobile phone "remote"	Mobile phone "proximity"
Cost	60%	4	3	3	1	2
Org. chan.	10%	3	3	3	1	1
Security	10%	1	3	3	4	2
Standard	20%	4	3	1	2	1

0 = weak; 1 = fair; 2 = average; 3 = good; 4 = excellent

*Source: designed from the text in the article entitled "A MULTI-ACTOR, MULTI-CRITERIA APPROACH FOR TECHNOLOGY SELECTION WHEN DESIGNING MOBILE INFORMATION SYSTEMS", page 4 – Jan Ondrus, Tung Bui and Yves Pigneur - 2005*

If a consensus between the major stakeholders is found, success probability of a global payment scheme based on a unique unanimous technology choice would be higher. They used a group decision approach called the min-max concept of game theory to search for this consensual solution. This method takes the most severe technology evaluations for each criterion done by any actor.

### 3.2.5.3 Conclusion

The mobile payment industry is highly uncertain, complex and variable. The model, in its results, shows that the experts' positions are contradictory for several technologies. The authors' advice is to conduct a re-evaluation of the preferences using a Delphi technique. This will allow more precise results to confirm the first insight given by the model. The use of a MCMD method can be helpful to study the market with a more structured and rational approach. Another capability of this tool is sensitivity analysis as changes can be simulated to observe which criteria or which expert could change the group consensus.

This constitutes a good example of partnership with the involvement of all types of stakeholders since the problem definition and onto the end of the process. It illustrates again the need for a holistic approach of the problem, the use of partnerships and the evaluation of new technologies against existing alternatives.

### 3.2.6 “Grey statistics method of technology selection for advanced public transportation systems– The experience of Taiwan”

### 3.2.7 “Technology selection for advanced public transportation systems in Taiwan using scenario method”

Both articles at 3.2.6 and 3.2.7 were written by researchers at the National Cheng Kung University in Taiwan. As they describe the same methodology for technology selection in transportation systems they will be covered together.

#### 3.2.7.1 Objective

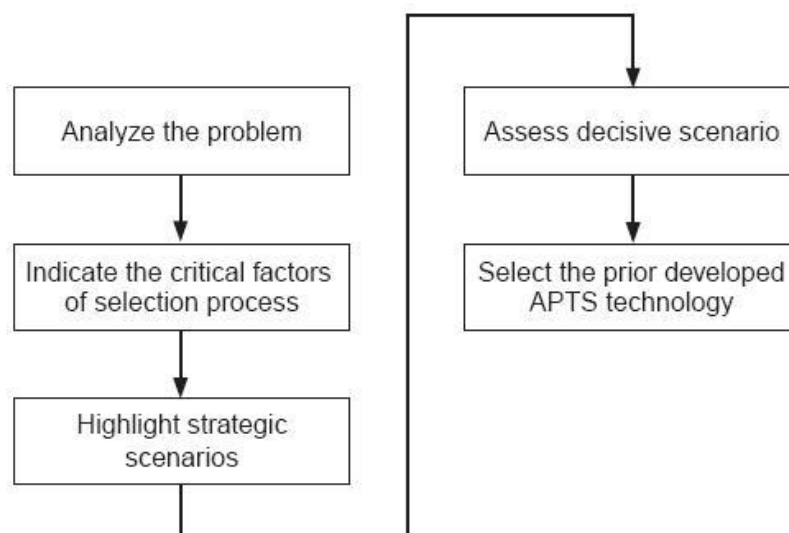
The authors define a technology selection decision as a method reflecting compatibility with innovative and existing technologies and risk of successful implementation. A technology selection process for advanced public transportation systems (APTS) is a new and complex decision process involving important cost and time uncertainties as well as uncertain political and economic situations in Taiwan.

Such methodology is needed to use national resources effectively. The scenario method described in this article is applicable to problems with larger future variability and with no historical data for reference.

#### 3.2.7.2 Methodology

A literature review was conducted to select the best APTS-related methodology for technology selection. The method chosen in these studies is based on a conceptual model with the use of grey statistics method for objective scenario building of APTS-related technology selection.

**Figure 7: The conceptual model of selecting APTS-related technology**



*Source: “GREY STATISTICS METHOD OF TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS – The experience of Taiwan” – Chien Hung WEI and Ming Chih CHUNG - 2003*

To establish the appropriate APTS development plan, they conducted a questionnaire survey on pre-specified key factors to determine the developmental priorities of the technologies and find a strategy that can meet the needs of both supply and demand sides. Survey respondent

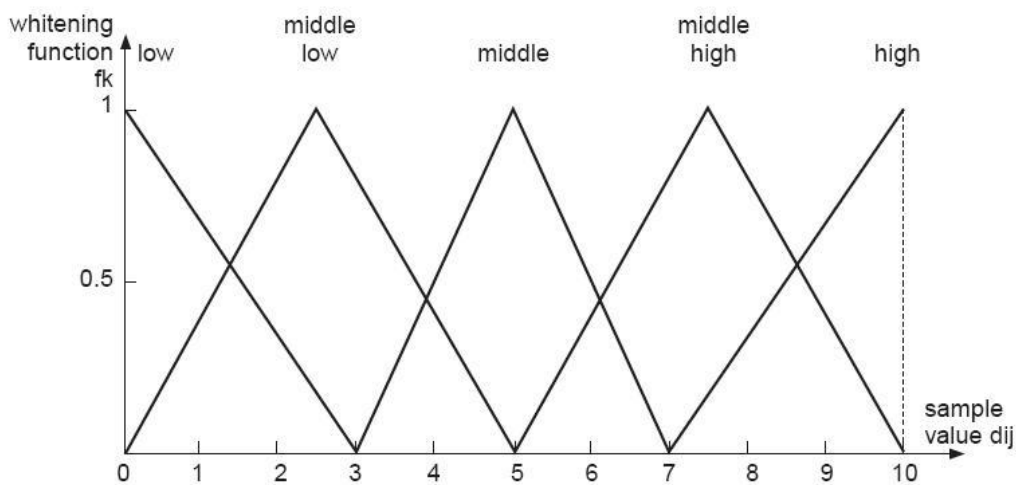
were first asked to present their opinion about the key factors of selecting technology, scoring on a 5-step scale bounded by 1 and 5, corresponding to “strongly disagreeable” and “strongly agreeable”. The positive integer they obtained here was referred to as the degree of comparative significance of factors. The second step is the formulation of basic scenario logics. In this exercise, respondent were asked to denote the base case scenario, the optimistic scenario, the pessimistic scenario and the likely future scenario.

Next step is the definition of developmental priority of APTS-related technology. This section was created to investigate the potential usefulness of six selected APTS-related technologies. Given the likely future scenario, survey respondents were asked to score the technologies on a nine-step scale to numerically denote the developmental priority of transport technologies. Four groups of people were included in this survey: (1) Researchers and professor, (2) the government representatives, (3) the APTS-related hardware/software providers (APTS technical suppliers), (4) public transportation business operators (APTS demanders). 33 samples were validated out of 66 samples collected from air Transport Corporation, Bus Company, mass rapid transit corporation, Taiwan railway administration and electronic corporation. They were asked to score their familiarity with Intelligent Transportation Systems (ITS) and APTS with a five-step scale going from ‘rather unfamiliar’ to ‘very familiar’. As much as 94% and 88% are respectively familiar with ITS and APTS.

The authors processed the raw data and developed scenarios by first analysing experts’ opinions with grey statistics method to process the unclear characteristics contained in their opinions. Grey statistics approach defines that the integration between experts’ opinion is clear so that it gives the same weight to all experts in the analysis. It uses gray numbers to classify influencing factors into different categories to better identify essential factors to construct the basic scenario logics and the decisive scenario.

This was done through a new questionnaire survey asking experts to assess the factors according to their potential importance. With the grey statistics method, the results precisely represent experts’ opinions. They converted the rank numbers into grey numbers from 9 to 1 (in five grey groups), so that the higher value represents greater importance. The grey groups can be illustrated as follows:

**Figure 8: Five grey groups**



Source: “GREY STATISTICS METHOD OF TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS – The experience of Taiwan” – Chien Hung WEI and Ming Chih CHUNG - 2003

The next step is to identify the whitening function. One example is the factor ‘user needs’, its grey statistics series [high, middle-high, middle, middle-low, low] is calculated as white values [9.38, 8.64, 0,0,0]. According to these results, this factor was categorised as “high”. Same was done for all factors and they were classified in grey groups as illustrated below:

**Figure 9: Relative grey group for each factor**

Influencing factor	Grey statistics series	Grey group
User needs	[9.38,8.64, 0, 0,0]	High
Specific knowledge demand	[2.01,8.36,5.00,0.67,0]	Middle-high
Infrastructure	[6.03,7.66,4.00, 0,0]	Middle-high
Local economic development	[4.02,6.67,6.00,0.67,0]	Middle-high
Dense networks of firms	[2.68,8.02,4.00,0.67,0]	Middle-high
Supporting organization	[5.34,5.36,1.00,0.67,0]	Middle-high
Local capital source	[3.35,5.67,7.00,1.34,0]	Middle
Stakeholders' opinions	[2.01,7.02,8.00, 0,0]	Middle
Professional worker	[6.70,9.33,1.00, 0,0]	Middle-high
Existing technical ability	[5.36,8.00,3.00,0.67,0]	Middle-high
Human resources training	[2.68,6.68,5.00,2.01,0]	Middle-high
Emissions	[ 0,8.71,7.00, 0,0]	Middle-high
Technological characteristics	[2.01,9.70,2.00,1.34,0]	Middle-high
Setting cost	[9.38,7.30,1.00,0.67,0]	High
Safety	[6.70,8.66,2.00, 0,0]	Middle-high

*Source: “GREY STATISTICS METHOD OF TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS – The experience of Taiwan” – Chien Hung WEI and Ming Chih CHUNG – 2003*

The authors selected factors belonging to “high grey group” and “middle-high grey group with highest white value” in constructing the strategic scenarios. The independent factors chosen were “user needs”, “setting cost” and “technological characteristics”.

They started the scenarios construction by combining two factors to both construct possible scenario and analyse consistency. See example below:

**Table 3: Possible situations for technology choice scenario structures**

		User needs	
		High	Low
Technological	Simple	Situation 1	Situation 3
Characteristics	Complicated	Situation 2	Situation 4

*Source: “GREY STATISTICS METHOD OF TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS – The experience of Taiwan” – Chien Hung WEI and Ming Chih CHUNG – 2003*

Then a third factor “setting cost” was added to the matrix allowing the authors to simulate eight reasonable scenarios. They interviewed experts to ask them to rate each scenario by the possibility of its occurrence in a strategic situation. When the results came back they analysed every scenario under the “likely future” situation using grey statistics method to determine the final decisive future scenario. Results are presented below:

**Table 4: Grey group of each scenario**

Scenario	Grey statistics series	Grey group
Scenario 1	[5.69,4.80,3.50,0.40, 0]	High
Scenario 2	[5.00,7.20,2.50,1.60, 0]	Middle-high
Scenario 3	[1.67,2.40,3.00,3.20,0.33]	Middle-low
Scenario 4	[0.33,1.20,1.50,4.80,0.99]	Middle-low
Scenario 5	[4.68,7.20, 0,0.80, 0]	Middle-high
Scenario 6	[2.00,4.40,1.50,0.80,0.33]	Middle-high
Scenario 7	[0.33,2.80,2.50,1.60, 0]	Middle-high
Scenario 8	[ 0,2.40,1.50,2.80,0.66]	Middle-low

*Source: "GREY STATISTICS METHOD OF TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS – The experience of Taiwan" – Chien Hung WEI and Ming Chih CHUNG - 2003*

**Table 5: Grey group of each technology**

Technology	Grey statistics series	Grey group
Short-range communications	[2.64,14.40,10.50,2.40,0]	Middle-high
Route guidance systems	[1.65,10.40, 6.00,7.20,0]	Middle-high
Automatic vehicle location systems	[3.63,14.00, 8.00,1.20,0]	Middle-high
Automatic vehicle monitoring systems	[0.99, 8.80,10.00,4.80,0]	Middle
Contactless smart card	[3.630,15.20, 6.00,2.40,0]	Middle-high
Combi card	[0.33, 8.40, 7.00,6.00,0]	Middle-high

*Source: "GREY STATISTICS METHOD OF TECHNOLOGY SELECTION FOR ADVANCED PUBLIC TRANSPORTATION SYSTEMS – The experience of Taiwan" – Chien Hung WEI and Ming Chih CHUNG – 2003*

### 3.2.7.3 Conclusion

This paper presents a well defined methodology to easily compare various technology alternatives using a limited set of criteria associated with a mathematical approach. It is an interesting approach as it is relatively simple and pragmatic. The process is very close to other articles described in this review starting with problem identification and using critical factors for technology selection. It could be easily applied in other sectors, but would require computer software capable of gathering all criteria and critical factors and of analysing the various scenarios. The designing of questionnaires to obtain maximum information from the stakeholders is an interesting part of the process and could be developed in other sectors to better focus the efforts where needed but could also be used to better catch public opinion on each of the alternatives if used differently on a website for example (online survey that would represent a living exercise).

The method was judged effective for the selection of new technology in APTS, both regarding transportation research and to analyse technology selection strategies quantitatively and successfully. The authors finally suggested that future research should aim at exploring the relationship between technological characteristics and technology sourcing.

### 3.2.8 “Marginal Analysis Guided Technology Evaluation and Selection”

#### 3.2.8.1 Objective

This research was conducted by the University of Nottingham, jointly with the University of Missouri and the Mie Chukyo University in Japan. Early Stage Technology (EST) evaluation methods are usually so mathematically elaborated that they are difficult to use by managers.

The authors propose here a better method that can evaluate the strategic value of EST investment under uncertain future. They advice managers to use the information and knowledge of past manufacturing technology (MT) projects to support future project evaluation and selection. Another important remark they formulate is that the system should be capable of learning *in situ* to adapt to changes in the business environment.

Three main objectives were presented for this selection method, which are: (i) “retain and reuse knowledge and experience from previous (successful and unsuccessful) projects as inputs to the evaluation of future projects,” (ii) “adapt to new knowledge and respond to significant events in the business environment”, and (iii) “extract information from the knowledge database to explain and justify this analysis.”

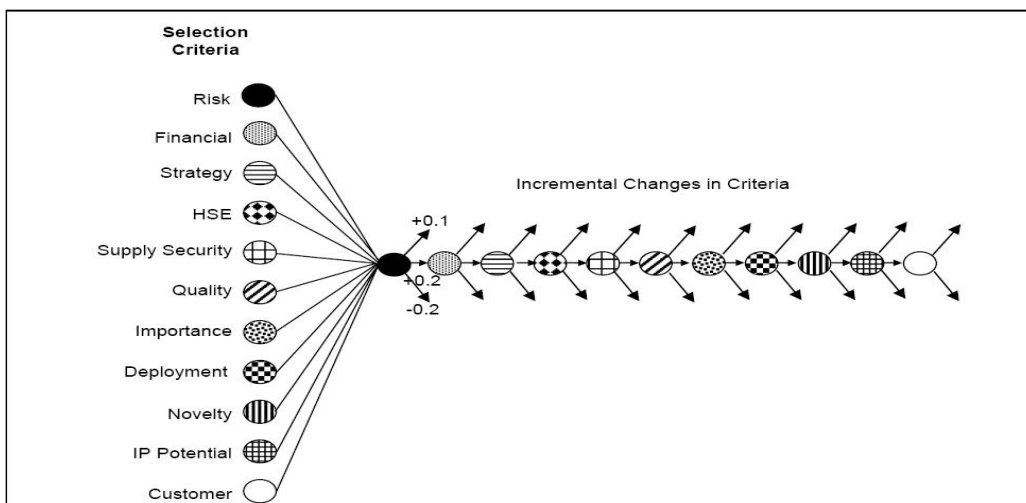
Often, technology selection methods combine both quantitative and qualitative data stretched over an extended period before a final decision can be made. A decision path capturing the logic behind the various decisions made over the course of a technology adoption process could provide both the decision support and corporate memory necessary to ensure success in the future. This paper proposes the use of marginal analysis-based branch and bound approach allowing an integrated risk / multi-criteria decision path to be developed. This approach is a sequence of transparent steps to provide clarity in the selection process.

#### 3.2.8.2 Methodology

As mentioned above, this methodology uses a marginal analysis directed branch and bound approach. A method for determining the effect of taking a given decision path is needed to analyse the trade-off between various decision paths.

They agreed that in such exercise most decisions are incremental in nature and that it would be appreciable that decision makers could be guided down the most promising path if a method of projecting the effects of each discrete decision were available. The concept of a decision path is illustrated hereafter.

**Figure 10: A Technology Selection Decision Path**



Source: “Marginal Analysis Guided Technology Evaluation and Selection” – Kim Hua Tan, James Noble, and Yuji Sato – 2007

In this figure, all priority and risk criteria are investigated sequentially starting from the criteria that is weighted the greatest.

The approach proposed in this article consists of determining an initial instance of the solution and then proceeds with different solution changes to determine which one provides the greatest marginal benefit. This methodology can serve as the basis of a combined multi-criterion (financial, strategy, health/safety, supply security, quality, importance, deployment, novelty, intellectual property, and customer service) and risk justification argument. It provides the reasoning from a marginal analysis to the justification of the selection of a specific aspect of the technology. The decision maker has to determine the selection criteria, and then analyse the effect of changing it.

The result of such an evaluation on both the technology alternatives and the decision criteria is that the final decisions will be fully justified. An additional benefit of an incremental method as opposed to an end-of-process one is that the rationale behind each decision can be captured (decision path) and can serve as the basis of an overall justification argument.

The various alternatives are evaluated with a branching and bounding method with respect to each alternative's performance for the selection criteria. In this process new alternatives are generated incrementally. The marginal analysis is initiated by establishing one alternative as the baseline, then by evaluating a second alternative relative to this baseline.

If the second alternative performs slightly better with respect to the highest ranked decision criterion and worse for other criteria, then the decision maker can reject this second alternative which is judged worse than the baseline one.

If the scoring of a third alternative is better with regards to the highest ranked decision criterion and other criteria, but is significantly worse with respect to one other criteria, then the decision to keep the third alternative will be taken. Two tables below illustrate this process with regard to four criteria (flexibility, compatibility, cost, and vendor reputation):

**Table 6: Primary Decision Criteria**

Criteria Priority Rank	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>
	<i>Flexibility</i>	<i>Compatibility</i>	<i>Cost</i>	<i>Vendor</i>
Alt 1	45	23	67	45
Alt 2	47	16	60	50

*Source: "Marginal Analysis Guided Technology Evaluation and Selection" – Kim Hua Tan, James Noble, and Yuji Sato – 2007*

**Table 7: Marginal Analysis on Alternatives 1 and 2**

	Alt1-0	Alt2	Alt2 vs Alt1	
Flexibility	45	47	4.4%	Ok
Compatibility	23	16	-30.4%	Not Acceptable
Cost	67	60	-10.4%	Not Acceptable
Vendor	45	50	11.1%	Good
				Reject A2

*Source: "Marginal Analysis Guided Technology Evaluation and Selection" – Kim Hua Tan, James Noble, and Yuji Sato – 2007*

The author uses this kind of comparison with a concrete example to illustrate the principle of the marginal analysis directed branch and bound method. This analysis is not designed to give

solutions, but rather to assist decision makers by capturing decision logic, and representing the branching and bounding decision process.

### **3.2.8.3 Conclusion**

This paper demonstrates the possibility of using a marginal analysis approach to support decision making in selecting new technologies. The marginal analysis is a useful method to evaluate alternatives with respect to all decision criteria (and particularly when they are numerous). The decision path provides the logic from a marginal analysis perspective as to why a specific aspect of the technology was selected, thereby keeping the corporate memory necessary to ensure success in the future.

This methodology assures both efficiency and effectiveness when selecting new technology alternatives and helps transforming opaque decisions into transparent ones. This approach has presented encouraging initial results, but further validation would be needed. The authors were planning to apply it to a few companies to reveal its value in the real environment.

#### 4. Conclusion

The review of all these very diverse Technology Identification and Selection methods from various sectors has shown that very different approaches exist with or without the use of complex mathematic models.

The first difficulty in such exercise is to clearly define whether a problem exists that needs technology to be solved and/or whether one wants to look at new technologies through literature searches to find applications in a particular area. Articles and programmes described in this paper cover both approaches to Technology Detection and Selection.

From articles using the first approach, we can conclude that it is not always easy to define the starting problem and then select new technologies or processes potentially suitable to solve it. Intervention of experts in the concerned sector but also in technologies seems very helpful to complete these first compulsory steps when identifying and selecting innovative technologies.

An important point to consider is to choose a method allowing the recording of all decisions taken (success or failure) to keep a memory of the past selections and facilitate review of the chosen methodology to constantly adapt to changes in the 'real' environment. All methodologies presented along this paper involve scoring methods and the definition of a set of criteria to evaluate different technology alternatives against those criteria, but also against each other. The incremental approaches seem highly interesting to better justify final choices.

When starting with cutting edge technologies that seem to have potential application for various uses, a burden is to ensure a wide scanning in a large number of sectors. Again, adapted expertise is compulsory for scanners to provide useful information and to keep them interested in their job. Participation in external conference and workshops is highly valuable to browse the widest picture and adopt a broad approach. Partnerships also represent a key source of diversity and innovation. Most of the forecast programmes create alliances with others to profit from each other.

Finally, IT tools have a relevant application in such methodology from mathematical software to help decide on alternative choices to complete websites allowing exchange of information, publication of trends and providing databases on existing and ongoing research in innovation. Public perception should also be looked at closely as a 'wonderful' technology with a great use can be rejected widely by the society and will not find any market.

DISCONTTOOLS Work Package 4 on "Technology Evaluation" will review the utility of adopting elements arising from these reviewed methodologies, and will keep on exploring and learning from any other existing experiences identified during the course of the DISCONTTOOLS project.

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